

**Beach Wizard**  
**Development of an Operational Nowcast, Short-Term Forecast System**  
**for Nearshore Hydrodynamics and Bathymetric Evolution.**

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## **LONG-TERM GOALS**

The long-term goals are to provide accurate and detailed predictions of nearshore hydrodynamics and bathymetric evolution using an advanced process-based model (Delft3D). Observations of dense remotely-sensed and sparse *in situ* data will be assimilated to continuously improve model performance, and where the data is uncertain or absent, the model will be used to fill in the gaps and construct a more complete estimate of current or near-future conditions.

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## OBJECTIVES

The objectives of the proposed study are to:

- Develop methods for estimating relevant Delft3D model inputs and outputs from airborne and shore-based video and radar observations.
- Develop and implement techniques to assimilate these data in Delft3D.
- Validate the assimilation model by hindcasting with the remote observations and sparse *in situ* data sampled from field experiments.
- Improve numerical model formulations to narrow error bands on model predictions
- Generate nowcasts and forecasts of the nearshore environment

## APPROACH

The approach is to develop an integrated nearshore modeling system that can be tested for a few sites where multiple information sources are available. We bring together a number of research groups with specific nearshore expertise, and experience with observations from different field sites including Duck (NC), Monterey (CA), La Jolla (CA), Egmond (NL), and Palm Beach (NSW). These field sites have distinctly different morphological characteristics and time-scales of response. Correspondingly, these sites have different remote sensing characteristics, which will provide an assessment of our proposed integrated modeling system's ability to nowcast and forecast in practical situations.

The central software in the system is the Delft3D model, which is available at NRL and for other ONR-sponsored institutions. This model is uniquely capable of modeling 2D and 3D hydrodynamics and morphodynamic changes over time-scales ranging from wave groups to several weeks, at spatial scales resolving rip-current cells and breaker bars (Reniers et al., 2004). In particular, model application at Palm Beach, NSW has contributed significantly to our understanding of nearshore morphodynamic processes (Reniers et al, 2001) showing the strong correlation between spatial distribution of computed wave energy dissipation and observed video intensity on a alongshore variable nearshore bathymetry.

The starting point of this work is the estimation of improved nearshore bathymetry via an iterative data assimilation scheme. Assimilation of (forward) model runs with observations is achieved by adding artificial morphological processes to the processes already in place. At present, the additional processes extract or add sediment to the bottom according to the mismatch between remotely sensed proxies for a wave dissipation parameter and its modeled equivalent. The prediction's sensitivity to the data is tuned by adjusting the both the time scale of model adaptation and the data de-correlation time scale. A recent pilot study incorporating spatial variations of nearshore variables derived from Argus video data into the Delft3D model showed good results for both field observations (at Egmond, NL, and Monterey, CA) and synthetic case studies (Roelvink et al, 2003).

We continue to develop and test this assimilation method for nowcasting and prediction purposes, following a three-step approach:

**A. Development and ground truthing of the assimilation model.**

Improvement of algorithms to extract video-and radar-derived nearshore variables that can be assimilated with the Delft3D model. An initial focus on hindcasting will use data from the NCEX experiment (La Jolla, CA) that enables the simultaneous incorporation of both video and radar data. Ground truth data were obtained approximately weekly and indicated slowly evolving bathymetry in a complicated wave environment

**B. Nowcasting of coastal evolution.**

Application of the assimilation model to quantify the evolution of nearshore processes at a diverse set of morphodynamically active sites including Duck, a nourished beach at Egmond (NL), a rip-channeled beach at Monterey and Palm Beach, Australia. Model performance will be evaluated against regular bathymetrical surveys at the various sites. The Beach Wizard will be expanded to assimilate an increased diversity of information sources, such as dense surface velocity estimates using video particle image velocimetry.

**C. Forecast of coastal evolution.**

Model-based forecast of hydrodynamic processes and coastal evolution at the time scale of a single week to extrapolate the hindcast and now cast predictions. We assume that the predictability of coastal evolution is primarily limited by the uncertainties associated with the process-based morphological model. Forecasts will be improved by recursively iterating on model parameters or model formulations, through comparison with real-time remote observations.

**WORK COMPLETED**

During this first year assimilation techniques, presently based on differences between video-based and computed dissipation, were incorporated into Delft3D and calibrated with data from the 1994 Duck94 field experiment. The model with the calibrated coefficients was used to perform a hindcast assimilation based on video data from the 1997 SandyDuck field experiment. Hydrodynamic simulations of the NCEX experiment were also performed. Inverse, data reduction techniques to schematize either 1-D or 2-D bathymetry were developed and are presently being incorporated into the Beach Wizard system.

**RESULTS**

To assess the feasibility of our approach, the assimilation model was tested against two field cases, one at Monterey and one at Egmond (Aarninkhof et al., 2005). The pilot applications have shown model capability to preserve the characteristic bar trough configuration, albeit that vertical deviations are considerable in absolute sense. Despite these deviations, it should be noted that the availability of this model in itself yields considerable added value as compared to the situation without any regular updates on surf zone bathymetry.

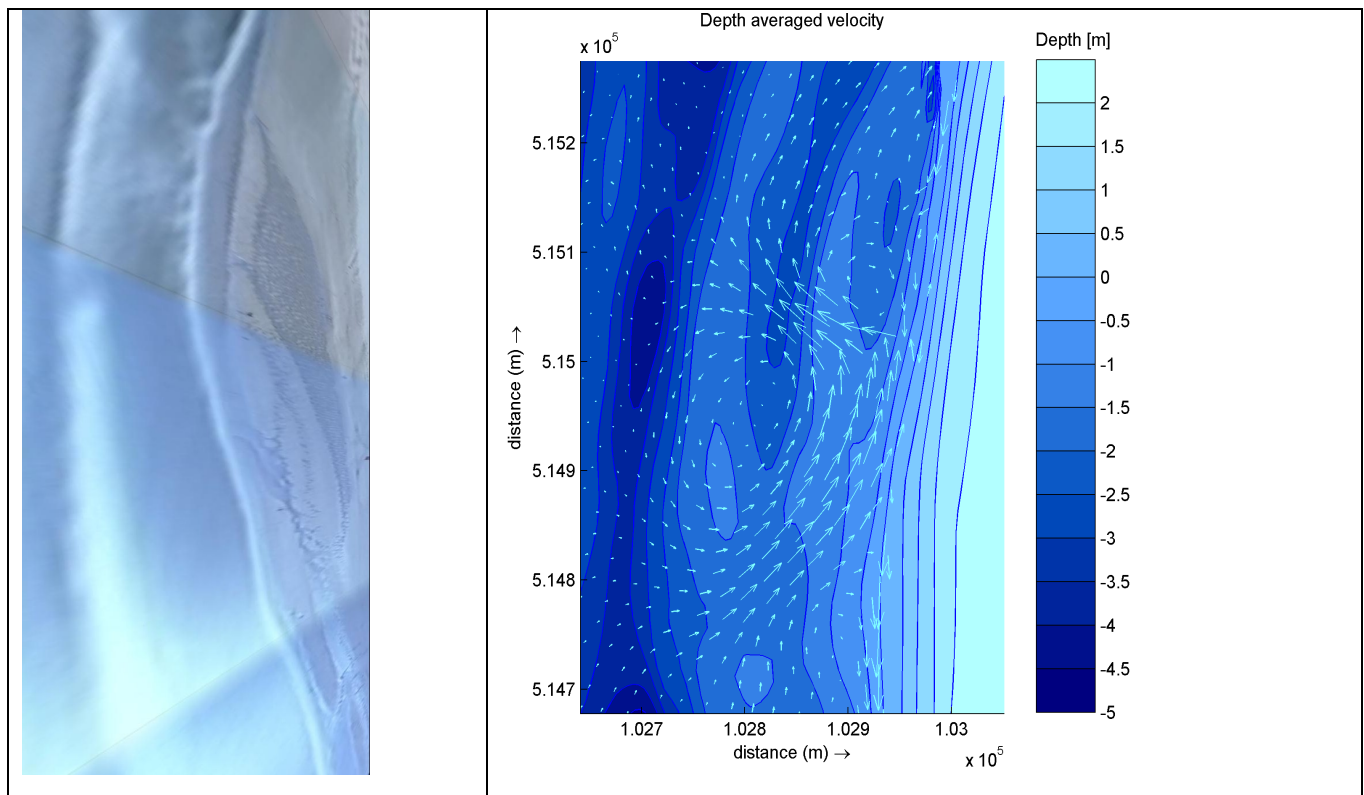
Promising model potential is further revealed from the realistic flow field computed in June 2000 (right panel of Fig. 1), showing a strong rip current crossing the inner bar. The corresponding plan-view video image of June 22 (left panel of Fig. 1) vaguely reveals a depression in the wave dissipation pattern at the same location, which may also reflect the presence of a rip current. The latter observation clearly highlights the potential of the combination of sophisticated models and high-resolution video.

The hydrodynamic (longshore current) calibration of the Delft3D model on the Duck94 data for a set of mild, moderate and storm conditions showed that a best fit for the breaker parameter was found at  $\gamma=0.65$ .

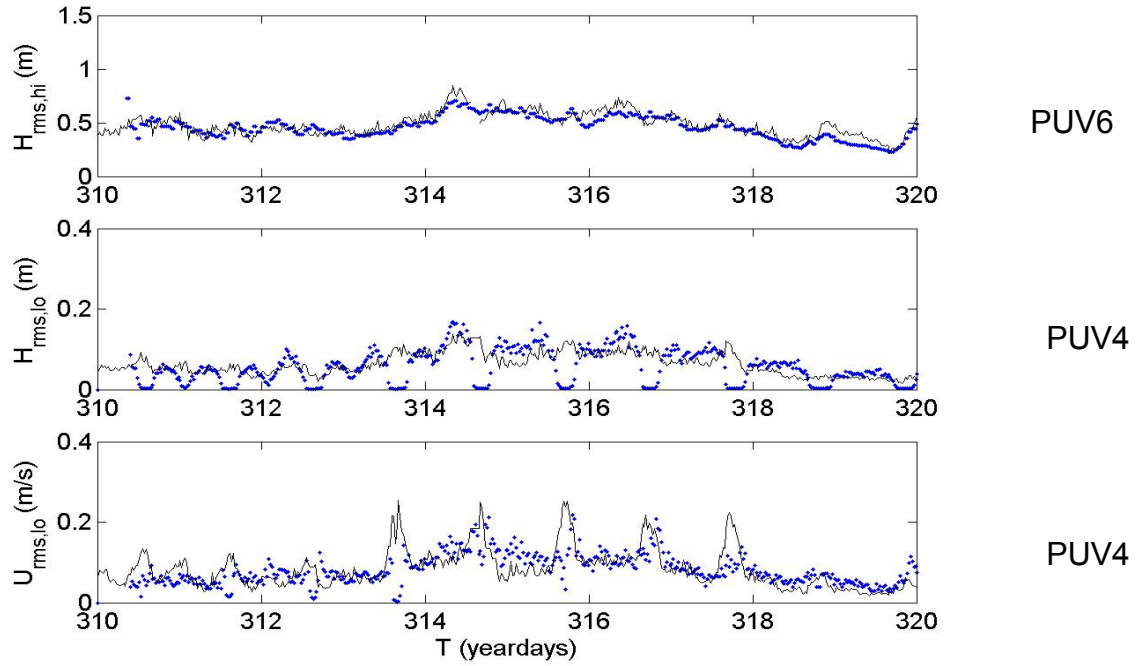
A calibrated Delft3D model for NCEX has been provided to the Beach Wizard project. The model showed good results (Figure 2) for both the mean and infragravity motions compared to the observations and is set-up to be compared with video-estimates of surface velocities derived from remote observations. The drop outs in the measured signal (blue dots) are due to the fact that the sensor was above the water level at that time due to low tide.

The calibrated Delft3D model for Duck was used for a morphological hindcast using the assimilation technique based on the difference in computed dissipation and Argus video-derived dissipation (Figure 3). The computed bottom profile (red solid line) has migrated from a starting bathymetry (red dashed line) to the target 1997 measurement (blue solid line), with the measured bathymetry at the start of the simulations (10/2/1997, blue-dashed) for reference. The rms-error in the measured versus computed bathymetry is reduced from about 1 meter to about 0.4 m. over the course of the simulation.

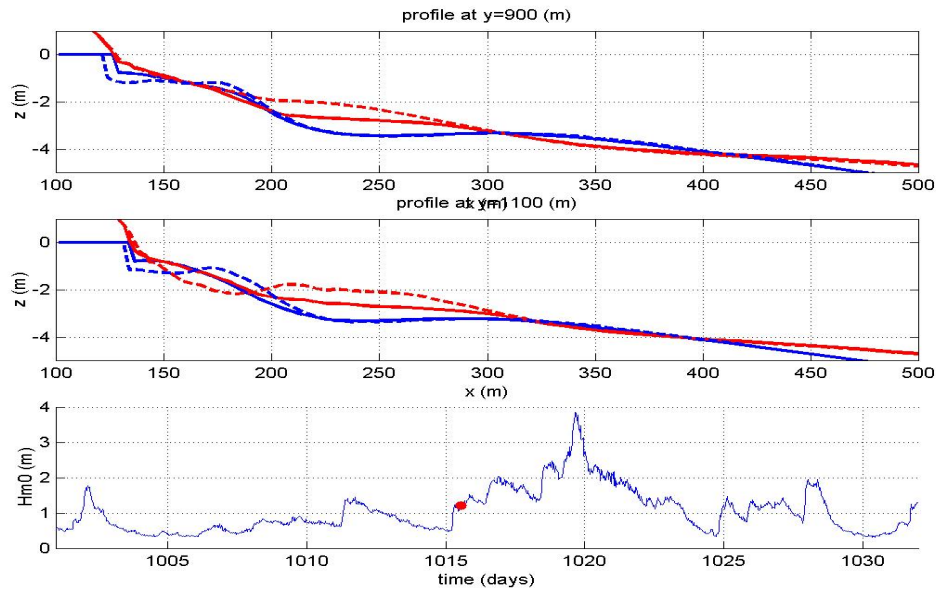
Finally, in a linked project sponsored by the Netherlands Science Foundation NWO, a sequential stochastic-deterministic search was used to determine optimal settings for the model parameters, followed by the quantification of bands of 95% depth uncertainty along the profile. 1D application of the model with optimized parameter settings yields substantially better results (Figure 4) along a cross-shore array in front of the Egmond light house. The results are obtained after nearly 1 year of simulation, using about 400 video-derived wave dissipation profiles to update subtidal bathymetry.



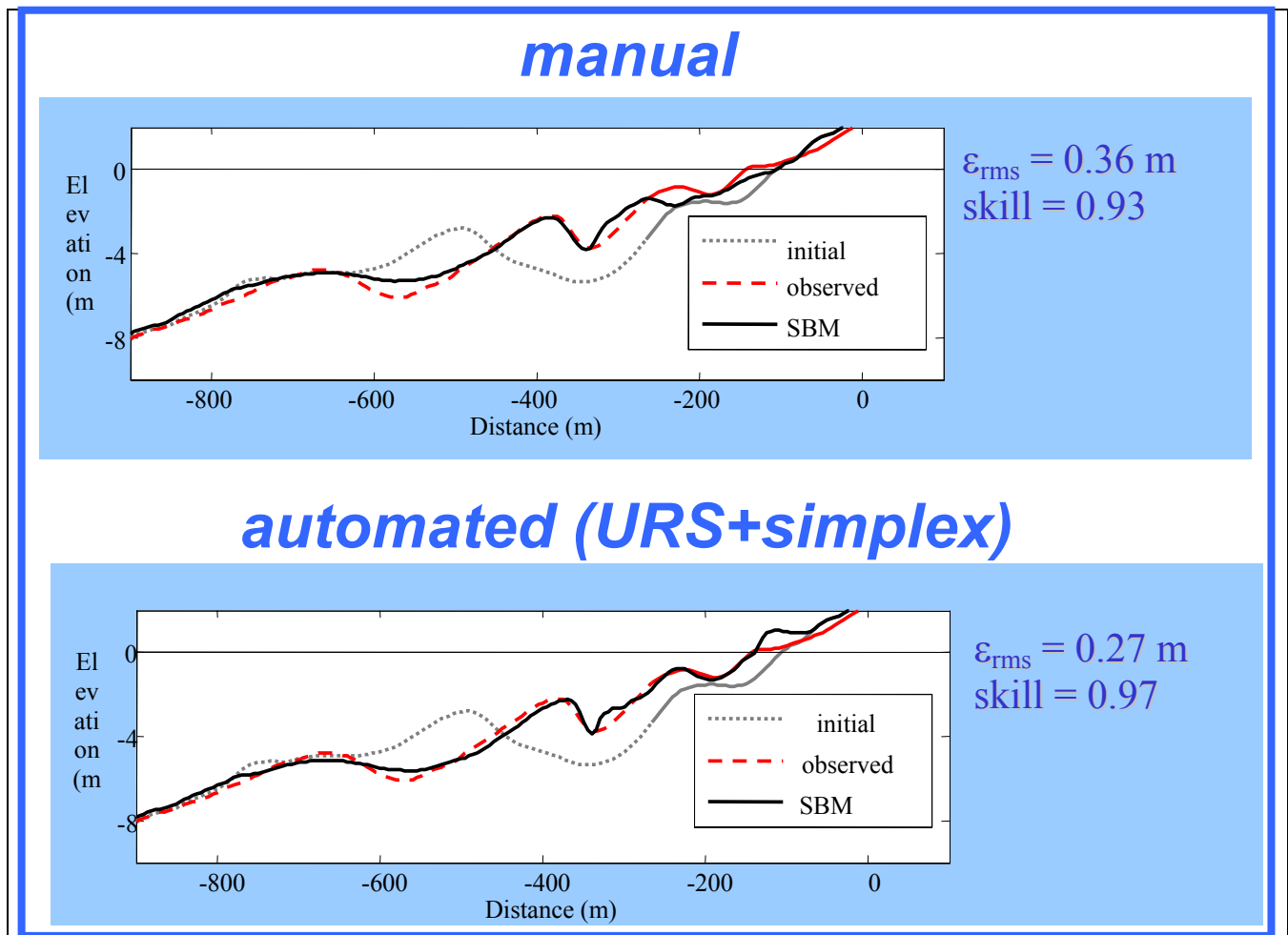
***Figure 1: : Plan-view Argus video image and computed flow field at Egmond, June 22, 2000. Both figures cover an area of 300 m cross-shore by 600 m alongshore. The video image reveals the presence of a rip channel in the central part of the nourished area, which is confirmed from the Delft3D calculations.***



**Figure 2: Measured (blue dots) and computed (solid line) high-frequency wave height (top panel), low-frequency wave height (middle panel) and low-frequency rms velocity (bottom panel).**



**Figure 3: Computed (red line), initial bathymetry for computations (red dashed line), measured at 10/16 (blue line) and measured at 10/2 (blue dashed) at two cross-sections in Duck coordinates at 900 m (top panel) and 1100 m (middle panel). The time history of the offshore wave height is shown for reference in the bottom panel.**



**Figure 4:** Initial (dotted gray line, Sept. 1999), measured (dashed red line, May 2000) and computed (solid black line, May 2000) beach profile in front of the Egmond Jan van Speyk light house for manual (upper panel) and automated (lower panel) calibration of the model parameters. Model performance particularly improved in the regions of the inner bar and the outer trough.

## IMPACT/APPLICATIONS

In addition to the importance to amphibious and special forces operations on beaches this research has benefits to predicting and mitigating the effects of beach erosion and accretion due to natural causes and coastal development and is therefore useful for coastal management.

## RELATED PROJECTS

Bluelink (<http://www.marine.csiro.au/bluelink/>) is a joint research effort between CSIRO, the Royal Australian Navy, and the Bureau of Meteorology, to deliver ocean forecasts for the Australian region. The highly successful first stage of this project is nearing completion with the delivery of a relocatable ocean model to the RAN. Bluelink2 is scheduled to begin in July 2006 with a particular emphasis on forecasting waves and currents in the littoral zone. Bluelink2 aims to combine numerical simulations



with measurements of nearshore waves, currents and bathymetry using remote sensing techniques such as radar and video, and in situ instrumentation. The objectives of Bluelink2 are closely related to the Beach Wizard objectives providing the opportunity to apply the assimilation techniques in a more operational environment.

Delft Hydraulics is executing a project in the context of coastal management for the Dutch Dept. of Public Works (Rijkswaterstaat) in the framework of the Ongoing Research Project (VOP). The application focuses on the evaluation of the efficiency of a combined beach and shoreface nourishment in Egmond, The Netherlands. In this project we will co-develop the assimilation techniques that are also used in the Beach Wizard project.

This work is collaborative with Dr. 's Haller and Holman (Oregon State University), Dr. Frasier (University of Massachusetts) and Dr. Plant (NRL-Stennis).

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